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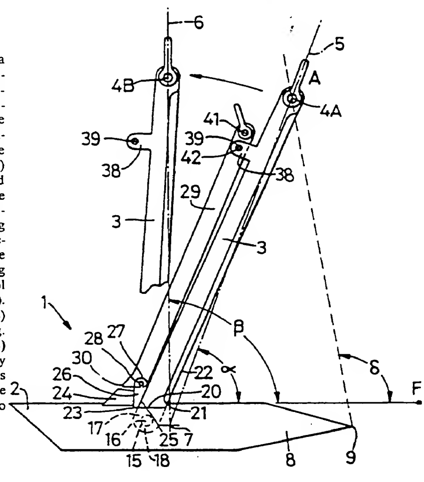
(57) Abstract

A marine anchor (1) comprising a fluke (8) and a shank (3) attached to the fluke (8) is intended for drag embedment in a mooring bed (63) by pulling the anchor (1) substantially horizontally via the shank (3). Further, it is a particular feature of the anchor that two modes of operation are possible by means of the line (5, 6) extending between the anchor cable attachement point (4A, 4B) on the shank and the fluke centroid (7) being variable to provide a first line (5) present for drag embedment of the anchor (1), and a second line (6) utilised when the anchor is embedded, wherein the pulling force on the anchor via the shank (3) can now be essentially upwards thereby providing an increased holding force due to the increased fluke area presented in the direction of the upwards force. The change in direction from the first line (5) to the second line (6) can be achieved by having the shank (3) pivoted (Fig. 9) and by providing pivot control means (26, 29) permitting selective pivoting of the shank (3). Alternatively two separate cable attachment points (4A, 4B) can be present in the shank (3) with, as a first example (Fig. 1), two separate cables attached to said points (4A, 4B) whereby the two modes of anchor operation are achieved by transferring operation from a first cable to the second, or as a second example (Fig. 6) moving the single anchor cable (64) via a guide (11) from the first attachment point (4A) to the second (4B).



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DRAG EMBEDMENT MARINE ANCHOR

The present invention relates to drag embedment marine anchors.

A requirement of a drag embedment marine anchor comprising a fluke attached to a shank is an ability to dig deeply into a mooring bed. The holding capacity is directly related to depth of embedment below the surface of the mooring bed. The ability to dig into the mooring bed soil depends on the anchor having a fluke angle appropriate for the particular soil present in the mooring bed. The fluke angle is usually defined as the angle between the forward direction of the fluke and a line connecting the anchor cable attachment point on the shank to a point on the rear edge of the fluke measured in a fore-and-aft plane of symmetry of the anchor. In practice, this angle is about 50° for muds and about 30° for sands. The angle that a straight line containing the cable attachment point and the centroid of the fluke forms with the forward direction of the fluke is correspondingly in the range 60° to 70° for muds and 35° to 45° for sands where the fluke is of triangular or rectangular shapes with a length to breadth ratio in the usual range between 1 and 2. This latter angle may be regarded as the centroid fluke angle.

The angle of friction, ϕ, between a marine soil and a smooth steel anchor fluke is usually in the range 22° to 30° for sand and 6° to 14° for mud. Thus, the centroid fluke angle is always made less than $(90-\phi)$ degrees to ensure that a pulling force applied at the anchor cable attachment point causes the anchor to penetrate by sliding in the soil in the forward direction of the fluke and so bury increasingly below the surface of the mooring bed when pulled horizontally thereon.

A deeply buried marine drag embedment anchor is usually recovered by heaving vertically upwards on the anchor cable attached to the forward end of the anchor

shank or by heaving vertically upwards on a pendant cable attached to the anchor at the rear edge of the fluke. This vertical pull first rotates the anchor in the soil until the centroid of the fluke lies vertically below either the cable attachment point on the shank (referred to as the break-out position) or the pendant cable attachment point at the rear edge of the fluke. When heaved up by the anchor cable, following rotation, the anchor simply continues "digging" in the forward direction of the fluke but obliquely to the vertical instead of obliquely to the horizontal until it emerges from the surface of the mooring bed. When heaved up by the pendant cable, following rotation, the anchor moves vertically upwards in the soil since the vertical cable lies in the rotated direction of the fluke.

The breaking-out force is least when heaving up by the pendant cable and greatest when heaving up by the anchor cable. Peak breaking-out force occurs in the anchor cable immediately following rotation of the anchor and just before movement oblique to the vertical occurs. This peak breaking-out force in the anchor cable usually has a magnitude of approximately 20 to 30 per cent of prior peak horizontal embedment force in sands and of the order of 100 per cent in muds. Generally, minimisation of anchor breaking-out force is, inter alia, an objective of drag embedment anchor design.

In contrast, it is an object of the present invention to provide a drag embedment marine anchor and a method wherein the breaking-out force at the break-out position is maximised. It is another object of the present invention to provide a drag embedment marine anchor and a method wherein the holding capacity may be increased at a given depth of embedment in a mooring bed soil.

Yet another objective of the present invention is to provide a method of limiting the load developed by a marine anchor during drag embedment to permit dragging to a desired location at constant load prior to increasing the holding capacity at such desired location.

These objectives are met, in accordance with the present invention, by providing an anchor which embeds in a mooring bed soil when pulled at an anchor cable attachment point at a relatively small fluke centroid angle and which can be subsequently pulled at an anchor cable attachment point at a larger fluke centroid angle whereby movement of the anchor in the direction of the fluke against friction is substantially prevented.

According to the present invention, a marine anchor for drag embedment in a submerged soil includes a fluke and a shank means attached to the fluke and arranged to provide at least one attachment point for attachment of an anchor cable, said shank means being adapted such that the anchor provides two directions from the centroid of the fluke to said attachment point whereby, in relation to the forward direction of the fluke measured in a fore-and-aft plan of symmetry of the anchor, a first direction forms a first forward-opening angle with said forward direction and a second direction forms a second forward-opening angle with said forward direction greater than said first forward-opening angle whereby pulling on the anchor at an attachment point located in said first direction permits drag embedment of the anchor by movement substantially in said forward direction in the soil whilst subsequent pulling on the embedded anchor at an attachment point located in said second direction precludes such movement and provides increased fluke area projected in the direction of the applied pulling force acting to resist movement of the anchor transverse to said forward direction.

Preferably, the first and second forward-opening angles are chosen with regard to the angle of friction, ϕ, between the fluke surface and the marine soil in which the anchor is to be embedded, whereby the first forward-opening angle is less than $90-\varphi$ degrees and the second forward-opening angle is in the range $90 \pm \phi$ so that embedment occurs when the anchor is pulled horizontally by the cable and horizontal slippage is pevented when the

fluke is finally horizontal and the anchor is pulled vertically by the cable.

Since the soil is disturbed aft of the anchor and undisturbed forward of the anchor, it is further preferred that the second forward-opening angle lies in the range 90 $\pm \phi$ and, more particularly, to lie in the range 84 to 90 degrees for mud operation and 68 to 90 degrees for sand operation.

A preferred first embodiment of the present invention provides a marine anchor which includes a shank providing first and second attachment points for an anchor cable and further preferably includes cable attachment transfer means whereby an anchor cable attachment means may be relocated from said first attachment point to said second attachment point following drag embedment of the anchor.

Preferably said first embodiment provides a marine anchor which includes slotted guide means between said two attachment points to permit sliding movement of an anchor cable attachment point to said second attachment point and further preferably said shank is of substantially triangular shape in side elevation, attached adjacent one apex to said fluke, and provided with an attachment hole adjacent each remaining apex to receive a shackle pin for attachment of an anchor cable thereto, and a slot linking said holes centrally for the hole lying in said first direction and offset towards the fluke for the hole lying in said second direction whereby an upwards and rearwards pull on the anchor cable following drag embedment of the anchor causes the shackle pin to slide from said first-direction hole to lodge in said second-direction hole.

A preferred second embodiment of the present invention provides a marine anchor which includes a shank adapted at an end remote from the fluke to form an anchor cable attachment point and at least a portion of said shank including said attachment point is pivotable about an axis transverse to said plane of symmetry, and said anchor includes first restraint means to restrain the shank such that the anchor cable attachment point lies in

said first direction during drag embedment of the anchor, and first restraint release means whereby the restraint means can be released to permit pivoting of said shank to occur to allow the anchor cable attachment point to be moved into said second direction by pulling on the anchor cable following completion of embedment of the anchor.

Preferably a marine anchor according to the second embodiment includes second restraint means to halt pivoting of said shank when the cable attachment point lies in said second direction.

Preferably said second restraint means includes a stop fixed to at least one of the shank and the fluke.

Preferably said stop comprises a locking stop which locks the shank to the fluke.

Preferably said first restraint means comprises a breakable member linking the shank to the fluke, said breakable number being breakable when a designated vertical load applied to the shank is exceeded by pulling upwards following drag embedment of the anchor.

Preferably said breakable member comprises a shearable pin linking the shank to the fluke adjacent said pivot.

Preferably the pivot axis is located adjacent the centroid of the fluke and the breakable member is located adjacent the pivot axis such that unit force in the anchor cable in said first direction at a small separation from the pivot axis induces a much smaller force in said breakable member during drag embedment of the anchor than unit force in the anchor cable when pulling subsequently in a vertical direction having a much larger separation from the pivot axis so that a vertical force considerably smaller than the drag embedment force can break the breakable member and rotate the shank into said second direction.

Preferably said first restraint release means is remotely actuable from above the surface of the mooring bed.

Preferably the first restraint release means is remotely actuable by a control pendant cable attached thereto whereby a vertical pull applied to said control pendant cable actuates said first restraint release means.

Preferably the first restraint release means comprises a removable wedge stop located between shank and fluke aft of the pivot and attached to said control pendant cable whereby a vertical pull on the control pendant cable following drag embedment of the anchor removes said wedge stop from the anchor and so releases the restraint.

Preferably said control pendant cable is attached to one end of an elongate lever member which is pivotably attached at another end to the wedge stop, said other end provided with a protruding toe serving to bear on the fluke to act as a fulcrum thereon whereby rotation of the lever member about said fulcrum caused by a vertical pull on the control pendant cable prising the wedge stop free from between the shank and the fluke.

Preferably the lever member is attached at the control pendant attachment end to the shank adjacent to anchor cable attachment point by releaseable attachment means actuable by the control pendant cable.

Preferably the releasable attachment means is actuated by application of a pulling force in the control pendant cable in excess of a designated value.

Preferably the releaseable attachment means includes a breakable member which breaks at said designated value of pulling force in the control pendant cable to release said attachment means.

According to a further aspect of the present invention, a method of controlling the load developed by a marine anchor during drag embedment when pulled in a mooring bed by an anchor cable attached thereto involves:

(a) attaching a control pendant cable to a portion of the anchor shank or to a rearward portion of the anchor cable attached to said shank to enable rotation of the anchor to

reduce the angle of inclination of the anchor to the horizontal;

(b) laying out the anchor on the mooring bed and pulling horizontally on the anchor cable to cause embedment of the anchor into the mooring bed;

(c) measuring the load developed in the anchor cable as embedment progresses;

(d) pulling upwards on the control pendant cable when the anchor cable load reaches a designated magnitude and maintaining a force in the control pendant cable sufficient to rotate the moving anchor and reduce the angle of inclination to the horizontal of the anchor fluke and so reduce the holding capacity of the anchor;

(e) noting the effect of the control pendant force on the measured load in the anchor cable;

(f) varying the force in the control pendant cable in accordance with the noted effect to control the anchor cable load to a constant designated value as the anchor is dragged to a desired installation location.

Preferably said control pendant cable is attached by remotely releaseable attachment means whereby said control pendant cable may be released and recovered following installation of the anchor.

Preferably the marine anchor employed in the above method is constructed according to the present invention.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings wherein:

Fig 1 is a side view of a marine anchor in accordance with a first embodiment of the present invention;

Fig 2 is a plan view of the anchor in Fig 1;

Fig 3 is a front view of the anchor in Fig 1;

Fig 4 shows a section P-P through a releasable coupling in the anchor in Fig 1;

Fig 5 shows the coupling of Fig 4 released;

Figs 1A to 3A show similar views to Fig 1 to 3 for a modified anchor;

Figs 6 to 8 show similar views to Figs 1 to 3 for a second embodiment of the present invention;

Figs 9 to 11 show similar views to Figs 1 to 3 for a third embodiment of the present invention including a pivoting anchor shank;

Fig 12 shows positions of parts of the anchor in Figs 9 to 11 following operation of a shank pivot release mechanism;

Fig 13 shows an alternative pivot stop mechanism for the anchor in Figs 9 to 11; and

Fig 14 shows a pictorial view illustrating operation of the invention.

Referring to Figs 1 to 5, a marine anchor 1 is symmetrical about a fore-and-aft plane M-M and comprises a fluke 2, a shank 3 attached to the fluke 2 adjacent the centroid 7 of the fluke and including a first anchor cable attachment point 4A comprising a hole at the shank end A furthest from the fluke 2, and a second anchor cable attachment point 4B at the outer end of a slotted hole at an aft position B on the shank between shank end A and fluke 2. Holes 4A, 4B serve to receive the pin of a shackle for attachment of an anchor cable. Fluke 2 comprises two fluke halves, 8, each of generally pentagonal shape in plan view with a foremost point 9 spaced from the plane of symmetry M-M. In front view, the planar upper surface of each half fluke forms an angle θ in the range 60 to 90 degrees with the plane of symmetry M-M. The ratio of length to width of the fluke in plan view is preferably in the range 1 to 2.

The forward direction F of the fluke 2 is defined by the line intersection of planar surfaces 10 with the plane of symmetry M-M and in the sense of moving from centroid 7 to point 9 in Fig 1. The centroid fluke angle α (the first centroid fluke angle) is the angle between the forward direction F of fluke 2 and a straight line 5 containing centroid 7 and cable attachment point 4A and is less than $(90 - \phi)$ degrees, where ϕ is the angle of friction between the anchor and the soil in which it is to

be embedded. The magnitude of ϕ is taken to be 30 degrees for sands and 15 degrees for muds for the purpose of determining α. Angle α is shown as about 70 degrees (for mud) in Fig 1, i.e. less than 75 degrees. The fluke point angle is the angle between the forward direction F of fluke 2 and a straight line containing the first cable attachment point 4A and the projection of fluke points 9 in the plane of symmetry M-M and is in the range 90 degrees to 110 degrees for soft mud and 50 degrees to 70 degrees for sand. Angle is shown as 100 degrees in Fig 1 for mud.

The straight line 6 containing the fluke centroid 7 and the second cable attachment point 4B forms an angle ß (the second centroid fluke angle) with the forward direction F of the fluke in the range ($90 \pm \phi$) degrees. Angle ß is shown as 90 degrees for both mud and sand in Fig 1. The attachment point 4B is spaced 25 to 100 per cent of the fluke length above the fluke to prevent rotational instability of the fluke 2 about point 4B due to any soil pressure distribution variations over the fluke.

Shank 3 is of plate construction of thickness less than 5 per cent of the fluke width and bevelled on the forward edge to minimise resistance to penetration of the shank into a mooring bed soil. In side view, the shank 3 is of Y-shape with a longer upper limb 3A inclined approximately at angle α to direction F and a shorter upper limb 3B inclined at angle ß to direction F and with a short lower limb 3C of the Y-shape attached to fluke 2 adjacent the fluke centroid 7. In front view, the fluke 2 has maximum depth of section in the plane of symmetry M-M and minimum depth of section distal to M-M, being of generally wedge-shape at each side of M-M and being hollow double-skinned plate construction of minimum frontal cross-sectional area to minimise resistance to penetration in the soil in direction F. Overall, the ratio of plan area of the anchor to area of the anchor projected in direction F is maximised consistent with preserving

adequate structural strength so that resistance to motion in direction F is as small as possible whilst resistance to movement at right angles to direction F is as large as possible.

Shank limb 3A is removably mounted on shank limb 3B by means of a pair of lugs 43 attached to the end of limb 3A remote from end A. Lugs 43 are spaced to fit one at each side of limb 3B and have coaxial holes 44 which align axially with a hole 45 in limb 3B to form a clevis and is pinned to limb 3B by means of two cylindrical pins 46 (Figs 4 and 5). Pins 46 abut against two pistons 47 fitted with oils seals 48 and lying back-to-back abutting against each other in plane M-M at the centre of hole 45. The pistons 47 have facing bevels 49 which form an annular oil chamber fed by oil through drilled oil-way 50 connected to oil supply pipe 51. Pin travel stops 52 are bolted onto lugs 43 to stop extrusion of pins 4 by oil pressure in hole 45 when the abutting faces 53 between pins 45 and pistons 47 are aligned with the outer surfaces of limb 3B. Faces 53 are adhesively held together by means of a low shear strength adhesive such as epoxy resin which shears when a small load is applied by pulling on the first anchor cable attachment point 4A when faces 53 are in alignment with the outer surfaces of limb 3B.

Shank limb 3B is fitted with a slideable sleeve 54 having a hole 55 to receive a pin 56 of a shackle 57 for attachment of an anchor cable thereto. Hole 55 is positioned to co-operate with slotted hole 4B such that pin 56 passing through hole 55 and slotted hole 4B has a range of sliding movement, carrying sleeve 54 with it, defined by the slotted hole 4B. Coaxial holes 58 are present in sleeve 54 and limb 3B to receive a shearable pin 59 which locks sleeve 54 in the position wherein pin 55 is located at the end of slotted hole 4B nearest fluke 2. A pulling force exceeding the shear failure load of shearable pin 59 in a direction at right angles to direction F will shear pin 59 and move pin 55 (and so sleeve 54) away from fluke 2 by the travel allowed by

slotted hole 4B. A lug 60 is attached to the aft face of sleeve 54 and a similar lug 61 is attached to the aft face of limb 3B. An oil-filled hydraulic cylinder 62 is connected to lug 60 with its piston rod connected to lug 61. Cylinder 62 is connected by oil supply pipe 51 to the drilled oil-way 50 in limb 3B whereby movement of pin 55 along slotted hole 4B following shearing of pin 59 actuates cylinder 62 and pumps oil into hole 45 between pistons 47. This extrudes pins 46 from hole 45 and allows limb 3A to be pulled away from limb 3B on shearing of the adhesive between abutting faces 53 to permit recovery of limb 3A and the anchor cable attached thereto. An alternative arrangement is envisaged where the pin extrusion mechanism is located at attachment point 4A and in an anchor shackle attached thereto.

In this case, limb 3A would not be recovered with the anchor cable and would be constructed simply as an integral part of shank 3.

Yet another arrangement is envisaged (see Figs 1A to 3A) wherein the complete release mechanism for releasing the anchor cable attached to point 4A is deleted and points 4A and 4B have only round holes for receiving shackle pins. In this arrangement, limbs 3A and 3B are integral parts of shank 3 and a shearable shackle pin at point 4A permits recovery of a first anchor cable.

In the embodiment of Figs 6 to 8, the second anchor cable attachment point 4B is separated from the fluke by approximately one length of the fluke and connected to the first anchor cable attachment point 4A by a slot 11 in the shank 3 so that sliding movement of a shackle pin therein can transfer an anchor cable attached thereto from point 4A to point 4B. The axis of slot 11 intersects the centre of a shackle pin hole at point 4A but intersects a shackle pin hole at point B offset towards fluke 2 so that the shackle pin can lodge under load in the hole at point 4B. Generally, the anchor corresponds to the anchor shown in Figs 1 to 3 and like parts carry like references. Shank 3 is of triangular shape in side view with a triangular

aperture 12 therein to reduce weight. A lug 13 having a hole 14 is attached to shank 3 adjacent anchor cable attachment point 4B to receive a shackle pin for attachment of an anchor pendant cable thereby. The anchor of figs 6 to 8 will probably be more suited for lighter load applications eg for yachts and small boats.

In the embodiment of Figs 9 to 13, the first anchor cable attachment point 4A is physically moveable by virtue of shank 3 being rotatable about pivot 15 in the fluke 2 so that point 4A can move out of line 5 into line 6 to become point 4B corresponding to point 4B in Fig 4. The anchor corresponds to the anchor shown in Figs 1 to 3 and like parts carry like references. Pivot 15 has an axis 16 normal to the plane of symmetry M-M and located in the fluke 2 aft of fluke centroid 7 below planar surfaces 10. A pivot pin 17 serves to locate lug 18, comprising the end of shank 3 remote from end A, between two lugs 19 attached to the underside of the fluke. Shank 3 passes through aperture 20 in fluke 2 with a forward edge 21 of the aperture 20 abutting against the forward edge 22 of shank 3 which edge 21 serves as a stop to stop rotation of the shank 3 form forming a fluke centroid angle α less than that given for the embodiment of Figs 1 to 3.

A rearward edge 23 of aperture 20 and a stop 24 attached to fluke 2 can abut against a rearward edge 25 of shank 3 to stop rotation of shank 3 from forming an angle ß great than that given for the embodiment of Figs 1 to 3. A wedge-shaped stop 26 bearing a pin clevis 27 and pin 28 is removably interposed between edge 25 of shank 3 and stop 24 to lock shank 3 temporarily with point 4A in line 5. A stop removal lever 29 is pivotably attached at one end by pin 28 to clevis 27 on wedge-stop 26 and laid off lengthwise along rear edge 25 of shank 3. A toe 30 is formed on lever 29 adjacent pin 28 which can bear on stop 24 following rotation of lever 29 away from shank edge 25 and in turn act as a fulcrum for further rotation of lever 29 to prise wedge-stop 26 forcibly out of its position between stop 24 and edge 25 to permit shank 3 to rotate

into abutment with stop 24 and so bring point 4A out of line 5 into line 6. A spring loaded wedge stop (not shown) under the fluke is now free to move up between edge 21 and edge 22 to lock shank 3 with point 4A at location 4B in line 6. (An alternative stop and locking arrangement for shank 3 is shown in Fig 13 wherein a crank arm 31 is provided which bears on fluke plate 32 under stop 24 to restrict forward rotation of shank 3 instead of edge 22 bearing on edge 21. A hole 33 is provided at the extremity of arm 31 which aligns with a corresponding hole 34 in lugs 19 when shank 3 rotates to bring edge 25 into abutment with stop 24. A spring loaded bolt 35 is mounted in hole 34 in one of lugs 19 which threads hole 33 when aligned with holes 34 to lock shank 3 to lugs 19 with the anchor cable attachment point 4A in position 4B (Figs 12 and 13) and lying in line 6. Another hole 36 in arm 31 is provided which is in initial alignment with corresponding coaxial holes in lugs 19. A shearable pin 37 may be fitted in hole 36 to lock shank 3 to lugs 19 when point 4A is initially in line 5 whereby exceeding a designated moment of force about pivot axis 16 shears pin 37 and so allows shank 3 to rotate rearwards.

Shank 3 has clevis lugs 38 with coaxial holes 39 located on the rear edge 25 spaced approximately 20 per cent of the shank length from point 4A. Lever 29 (Figs 12 and 13) has a length of 0.8 times the length of shank 3 and has a lug hole 41 at an end remote from toe 30 to receive a shackle pin for connection thereto of an anchor pendant cable. Lever 29 also has a hole 40 for coaxial registration between lugs 38 with holes 39. A shearable pin 42 is fitted through holes 39 and 40 which is breakable by a designated force applied at hole 41 by pulling up on the anchor pendant cable. Further pulling up on the anchor pendant cable removes the lever 29 and wedge-stop 26 bodily from embedded anchor 1. This allows the fluke centroid angle to increase from α to β under the rotative moment about pivot axis 16 of soil forces

distributed over surfaces 10 of fluke 2 acting effectively at fluke centroid 7.

Referring now to Fig 14 and to Figs 1 to 12, in use an anchor according to the present invention is installed in a submerged mooring bed 63 by means of two cables 64, 65 attached thereto, with cable 64 attached at point 4A and with cable 65 attached at hole 4B by means of shackle 57 in the embodiment of Figs 1 to 3 or attached at hole 14 in the embodiment of Figs 6 to 8 or attached at hole 41 in the embodiment of Figs 9 to 11.

The anchor 1 is deployed from the deck of a first anchor handling vessel (AHV) 66 which pays out cable 64 from its winch drum. Cable 65 is passed to a second AHV 67 which pulls the anchor off the deck of AHV 66 into the water over the mooring bed. Anchor 1 is lowered into contact with the surface of mooring bed 63 by controlled paying out of the two cables 64, 65 so that anchor 1 contacts the mooring bed 63 fluke first with direction F aligned with the desired dragging path in the mooring bed. This contact point is chosen sufficiently distant from a desired installation position X that a desired tension in cable 64 is likely to be achieved or exceeded on dragging anchor 1 to position X by cable 64. Further paying out of cable 64 coupled with horizontal movement of AHV 66 rotates anchor 1 to bring shank end A into contact with the mooring bed surface and lays cable 64 out horizontally on the mooring bed 63 in the desired pulling direction. AHV 67 now pays out slack in cable 65 while AHV 66 pulls horizontally to cause anchor 1 to embed into the mooring bed and follow a burying trajectory 68 which, in turn, causes the tension in cable 64 to increase as anchor 1 approaches the desired installation position X.

If the build-up of tension in cable 64 measured by AHV 66 indicates that the desired tension will be exceeded before anchor 1 reaches position X, AHV 66 instructs AHV 67 to pull up on cable 65 to rotate anchor 1 in the mooring bed soil to decrease the inclination of fluke 2 to the horizontal and so reduce the digging capability and,

hence, the holding capacity of anchor 1 as it is dragged towards position X. By this co-operation between AHV 66 and AHV 67, anchor 1 may be dragged at a controlled constant tension in cable 64 and so follow a horizontal trajectory 69 in the mooring bed until position X is reached.

For the embodiment of Figs 1 to 3, following embedment at position X, the AHV 66 then slacks back on cable 64 while AHV 67 pulls up forcibly on cable 65 to break shear-pin 59 and actuate the hydraulic release mechanism hereinbefore described to release shank limb 3A together with attached cable 64 from anchor 1. AHV 66 then hauls in cable 64 to recover it together with shank limb 3A for subsequent re-use and moves off station. AHV 67 then applies more vertical pulling force to point 4B on anchor 1 to rotate fluke 2 until forward direction F is horizontal to obtain a vertical uplift resistance load considerably higher than the horizontal load applied by AHV 66, if high uplift resistance is desired. Alternatively, AHV 67 pays out cable 65 and moves to the position vacated by AHV 66 and applies a high horizontal pulling force to cable 65 to rotate anchor 1 so that fluke forward direction F is at right angles to the axis of cable 65 at point 4B to obtain a horizontal resistance load in cable 65 considerably higher than the horizontal load applied by AHV 66, if high horizontal restraint is desired.

For the embodiment of Figs 6 to 8, with a shearable shackle pin fitted in hole 14, following embedment of the anchor 1 at position X, AHV 67 pulls up forcibly on cable 65 to break the shearable shackle pin and release cable 65 for recovery onboard. AHV 67 then moves off-station. AHV 66 hauls in cable 64, moves aft of anchor 1 and pulls forcibly upwards and backwards to cause a shackle attaching cable 64 to point 4A to slide along slot 11 to lodge the shackle pin in the offset hole at point 4B. To achieve high vertical restraint load in cable 64, AHV 66 then moves vertically over anchor 1 and pulls forcibly on

cable 64 to rotate the anchor by load applied at point 4B to bring fluke forward direction F into the horizontal. Alternatively, to achieve high horizontal restraint load in cable 64, AHV 66 pays out cable 64 and moves back over anchor 1 again into the position it occupied when anchor 1 first reached position X. AHV 66 then pulls forcibly horizontally on cable 64 to rotate anchor 1 by application of load at point 4B until fluke forward direction F is at right angles to the direction of cable 64 adjacent point 4B.

For the embodiment of Figs 9 to 13, following embedment of the anchor 1 at position X, AHV 67 pulls forcibly on cable 65 to break shear pin 42, rotate lever 29, prise wedge-stop 26 clear of stop 24 and shank 3, and remove lever 29 bodily from anchor 1 for recovery on board of cable 65 and lever 29. To achieve high vertical restraint load in cable 64, AHV 66 then moves vertically over anchor 1 and pulls forcibly on cable 64 to rotate shank 3 into abutment with stop 24 and then rotate anchor 1 to bring fluke forward direction F into the horizontal. Alternatively, to achieve high horizontal restraint load in cable 64, AHV 66 simply pulls forcibly on cable 64 following removal of wedge-stop 26 to cause fluke 2 to rotate about axis 16 due to the offset moment of soil forces on fluke 2 acting at centroid 7 until stop 24 abuts against shank 3 where upon fluke forward direction F is at right angles to the direction of cable 64 adjacent shank end A.

It has been found from tests in a tank full of very soft mud using scale model anchors, constructed according to the present invention and deployed as described above, that the peak load obtainable in cable 65 can be as much as five times higher than the peak horizontal force in cable 64 required to embed the anchor until fluke points 9 are approximately five times the length of fluke 2 below the surface of the mud. In sand, similar tests show the peak load in cable 65 can be as much as about two and a half times higher than the peak horizontal force in cable

64 required to embed the anchor until fluke points 9 are approximately about two and a half times the length of fluke 2 below the surface of the sand.

These useful results have not hitherto been obtained from drag embedment anchors.

CLAIMS.

1. A marine anchor for drag embedment in a submerged soil comprising a fluke (8) and a shank means (3) attached to the fluke (8) and arranged to provide at least one attachment point (4A/4B) for attachment of an anchor cable (64), characterised in that said shank means (3) is adapted such that the anchor provides two directions (5, 6) from the centroid (7) of the fluke (8) to said attachment point (4A/B) whereby, in relation to the forward direction (F) of the fluke (8) measured in a fore-and-aft plane of symmetry (M-M) of the anchor, a first direction (5) forms a first forward-opening angle (α) with said forward direction (F) and a second direction (6) forms a second forward-opening angle (ß) with said forward direction (F) greater than said first forward-opening angle (α) whereby pulling on the anchor at an attachment point (4A) located in said first direction (5) permits drag embedment of the anchor by movement substantially in said forward direction (F) in the soil whilst subsequent pulling on the embedded anchor at an attachment point (4B) located in said second direction (6) precludes such movement and provides increased fluke area projected in the direction of the applied pulling force acting to resist movement of the anchor transverse to said forward direction (F).

2. A marine anchor as claimed in claim 1, characterised in that the shank (3) provides first and second attachment points (4A, 4B) for an anchor cable (64).

3. A marine anchor as claimed in claim 2, characterised in that cable attachment transfer means are provided whereby an anchor cable attachment means is relocated from said first attachment point (4A) to said second attachment point (4B) following drag embedment of the anchor.

4. A marine anchor as claimed in claim 3, characterised in that slotted guide means (11) are provided between said two attachment points (4A, 4B) to permit sliding movement of an anchor cable attachment point to said second attachment point (4B).

5. A marine anchor as claimed in claim 4, characterised in that said shank (3) is of substantially triangular shape (Fig. 6) in side elevation, attached adjacent one apex to said fluke (8) and provided with an attachment hole (4A, 4B) adjacent each remaining apex to receive a shackle pin for attachment of an anchor cable thereto, and a slot (11) linking said holes (4A, 4B) centrally for the hole lying in said first direction (5) and offset towards the fluke (8) for the hole lying in said second direction (6) whereby an upwards and rearwards pull on the anchor cable (64) following drag embedment of the anchor causes the shackle pin to slide from said first direction hole (4A) to lodge in said second-direction hole (4B).

6. A marine anchor as claimed in claim 1, characterised in that the shank (3, Fig. 9) is adapted at an end remote from the fluke (8) to form an anchor cable attachment point (4A) and at least a portion of said shank (3) including said attachment point (4A) is pivotable about an axis (16) transverse to said plane of symmetry (M-M), and said anchor includes first restraint means (26) to restrain the shank (3) such that the anchor cable attachment point lies in said first direction (5) during drag embedment of the anchor, and first restraint release means (29) whereby the restraint means (26) can be released to permit pivoting of said shank (3) to occur to allow the anchor cable attachment point (4A) to be moved into said second direction (6) by pulling on the anchor cable (64) following completion of embedment of the anchor.

7. A marine anchor as claimed in claim 6, characterised in that second restraint means (24) are provided to halt pivoting of said shank (3) when the cable attachment point (4A) lies in said second direction (6).

8. A marine anchor as claimed in claim 7, characterised in that said second restraint means (24) includes a stop fixed to at least one of the shank (3) and the fluke (8).

9. A marine anchor as claimed in claim 8, characterised in that said stop comprises a locking stop (35) which locks the shank (3) to the fluke (8).

10. A marine anchor as claimed in claim 6, characterised in that said first restraint means comprises a breakable member (37) linking the shank (3) to the fluke (8), said breakable member (37) being breakable when a designated vertical load applied to the shank (3) is exceeded by pulling upwards following drag embedment of the anchor.

11. A marine anchor as claimed in claim 10, characterised in that said breakable member (37) comprises a shearable pin linking the shank (3) to the fluke (8) adjacent said pivot (16).

12. A marine anchor as claimed in claim 11, characterised in that the pivot axis (16) is located adjacent the centroid (7) of the fluke (8) and the breakable member (37) is located adjacent the pivot axis (16) such that unit force in the anchor cable (64) in said first direction (5) at a small separation from the pivot axis (16) induces a much smaller force in said breakable member (37) during drag embedment of the anchor than unit force in the anchor cable (64) when pulling subsequently in a vertical direction having a much larger separation from the pivot axis (16) so that a vertical force considerably smaller than the drag embedment force can break the breakable member (37) and rotate the shank (3) into said second direction (6).

13. A marine anchor as claimed in any one of claims 6 to 12, characterised in that said first restraint release means (29) is remotely actuable from above the surface of the mooring bed.

14. A marine anchor as claimed in claim 13, wherein the first restraint release means (29) is remotely actuable by a control pendant cable (65) attached thereto at an attachment point (41) whereby a vertical pull applied to said control pendant cable (65) actuates said first restraint release means (29).

15. A marine anchor as claimed in claim 14, characterised in that the first restraint means (26) comprises a removable wedge stop located between the shank (3) and the fluke (8) aft of the pivot (16) and attached to said control pendant cable (65) whereby a vertical pull on the control pendant cable (65) following drag embedment of the anchor removes said wedge stop (26) from the anchor and so releases the restraint.

16. A marine anchor as claimed in claim 15, characterised in that said control pendant cable (65) is attached to one end of an elongate lever member (29) which is pivotably attached at another end to the wedge stop (26), said other end provided with a protruding toe (36) serving to bear on the fluke or associated part (24) to act as a fulcrum thereon whereby rotation of the lever member about said fulcrum caused by a vertical pull on the control pendant cable (65) prises the wedge stop (26) free from between the shank (3) and the fluke (8).

17. A marine anchor as claimed in claim 16, characterised in that the lever member (29) is attached at the control pendant attachment end (40) to the shank (3) by releasable attachment means (42) actuable by the control pendant cable (65).

18. A marine anchor as claimed in claim 27, characterised in that the releasable attachment means (42) is actuated by application of a pulling force in the control pendant cable (65) in excess of a designated value.

19. A marine anchor as claimed in claim 18, characterised in that the releasable attachment means (42) includes a breakable member which breaks at said designated value of pulling force in the control pendant cable (65) to release said attachment means (42).

20. A marine anchor as claimed in any one of the preceding claims, characterised in that said second forward opening angle (ß) lies in the range $90^{\circ} \pm \phi$ where ϕ is the angle of friction of the mooring bed soil in which the anchor is to be buried.

21. A marine anchor as claimed in claim 20, characterised in that the said second forward opening angle (ß) lies in the range 68° - 112° especially for sand.

22. A marine anchor as claimed in claim 20, characterised in that said second forward opening angle (ß) lies in the range 84° - 96°, especially for mud.

23. A method of controlling the load developed by a marine anchor having a shank (3) and fluke (8) during drag embedment when pulled in a mooring bed by an anchor cable (64) attached thereto characterised by:

(a) attaching a control pendant cable (65) to a portion of the anchor shank (3) or to a rearward portion of the anchor cable (64) attached to said shank to enable rotation of the anchor to reduce the angle of inclination of the fluke to the horizontal;

(b) laying out the anchor (1) on the mooring bed and pulling horizontally on the anchor cable (64) to cause embedment of the anchor (1) into the mooring bed;

(c) measuring the load developed in the anchor cable (64) as embedment progresses;

(d) pulling upwards on the control pendant cable (65) when the anchor cable load reaches a designated magnitude and maintaining a force in the control pendant cable (65) sufficient to rotate the moving anchor (1) and reduce the angle of inclination to the horizontal of the anchor fluke and so reduce the holding capacity of the anchor (1);

(e) noting the effect of the control pendant force on the measured load in the anchor cable (64);

(f) varying the force in the control pendant cable (65) in accordance with the noted effect to control the anchor cable load to a constant designated value as the anchor is dragged to a desired installation location.

24. A method as claimed in claim 23, characterised in that said control pendant cable (65) is attached by remotely releasable attachment means (42) whereby said control pendant cable (65) may be released and recovered following installation of the anchor.

25. A method as claimed in claim 23 or 24, utilising an anchor as claimed in any one of claims 1 to 22.

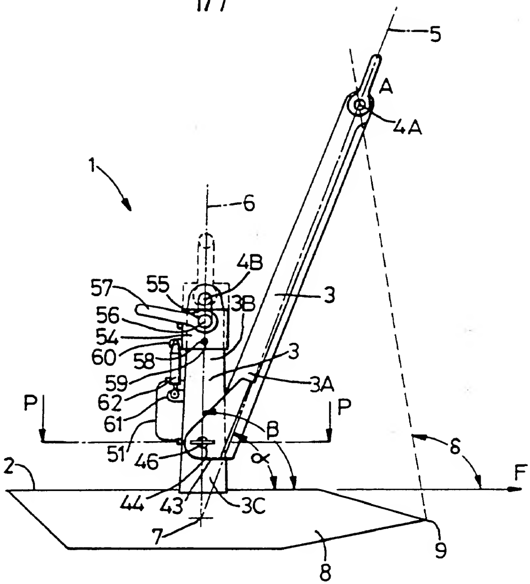

Fig.1

1) Trekken aan 6 ↑
2) 54 omhoog
3) cil. 62 pompt olie in via 51 tegen pennen 46 (fig 5,6)
4) pennen 46 naar buiten
5) 3A los.

Alt.
ander mechanisme t.p.v. 4B.

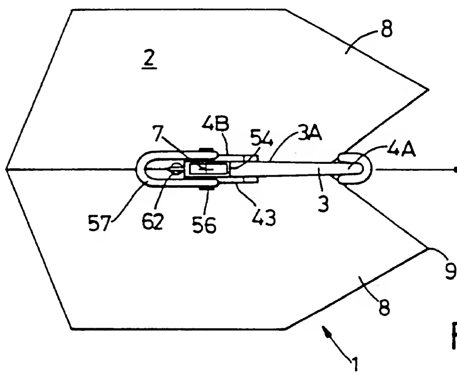

Fig.2

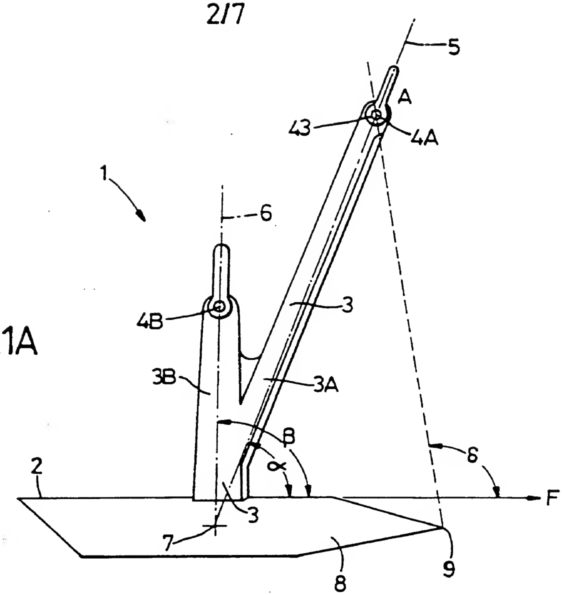

Fig.1A

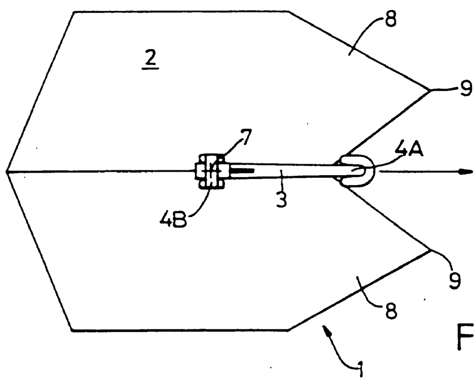

Fig.2A

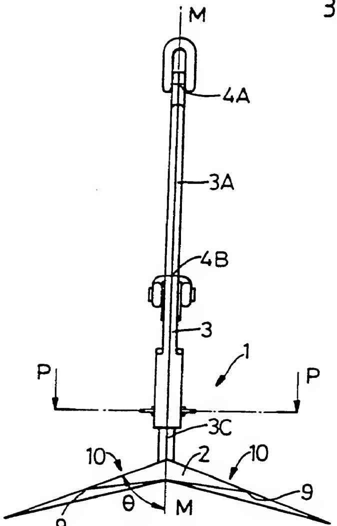

Fig.3

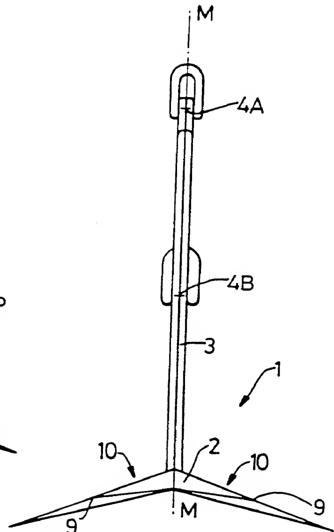

Fig.3A

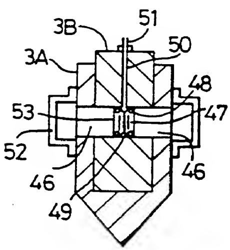

Fig.4

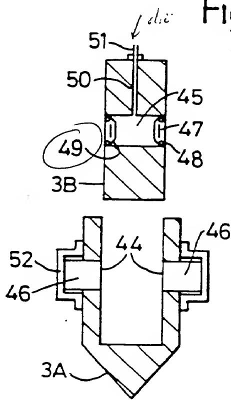

Fig.5

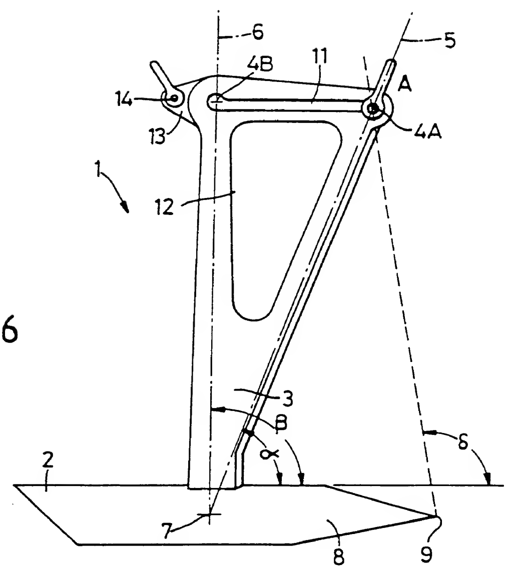

Fig. 6

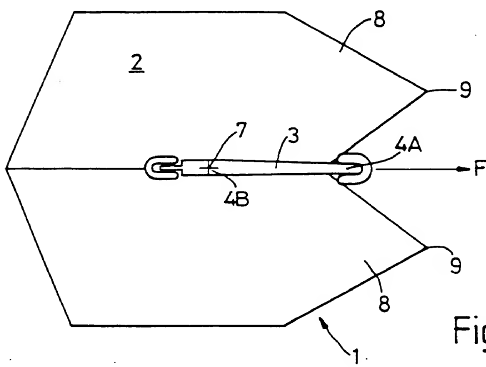

Fig.7

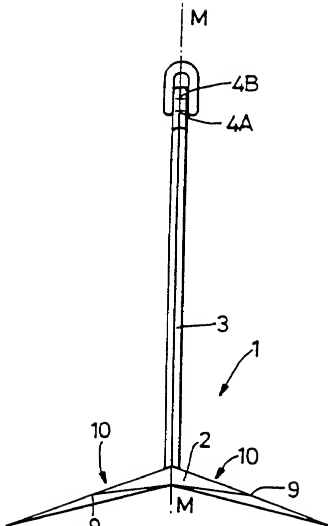

Fig.8

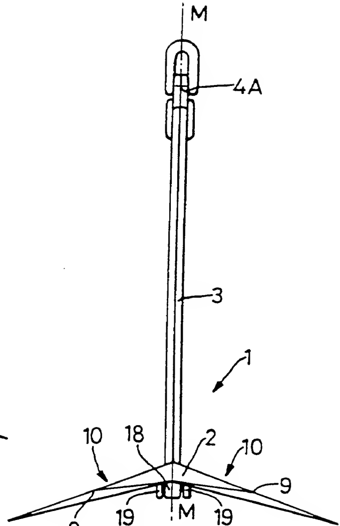

Fig.11

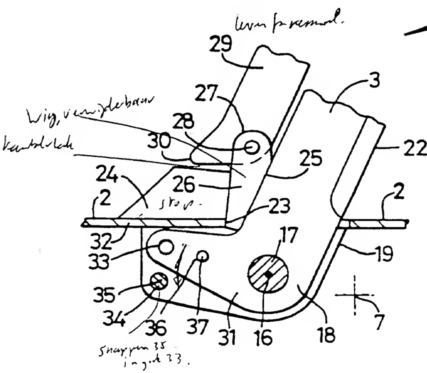

Fig.13

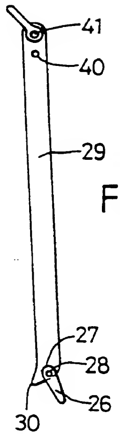

Fig.12

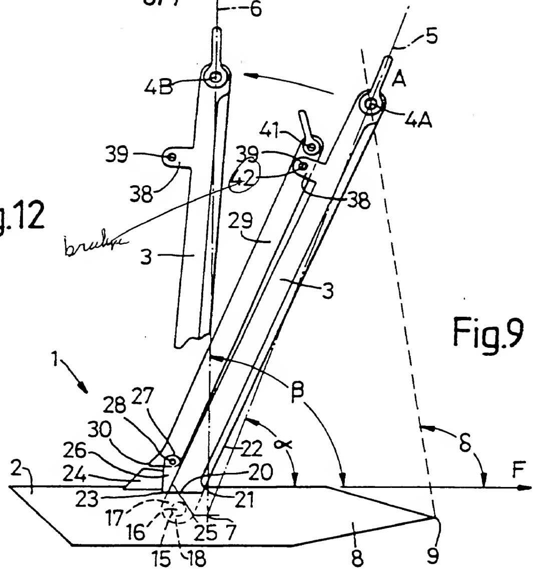

Fig.9

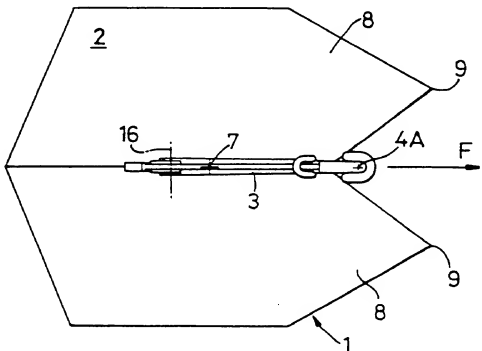

Fig.10

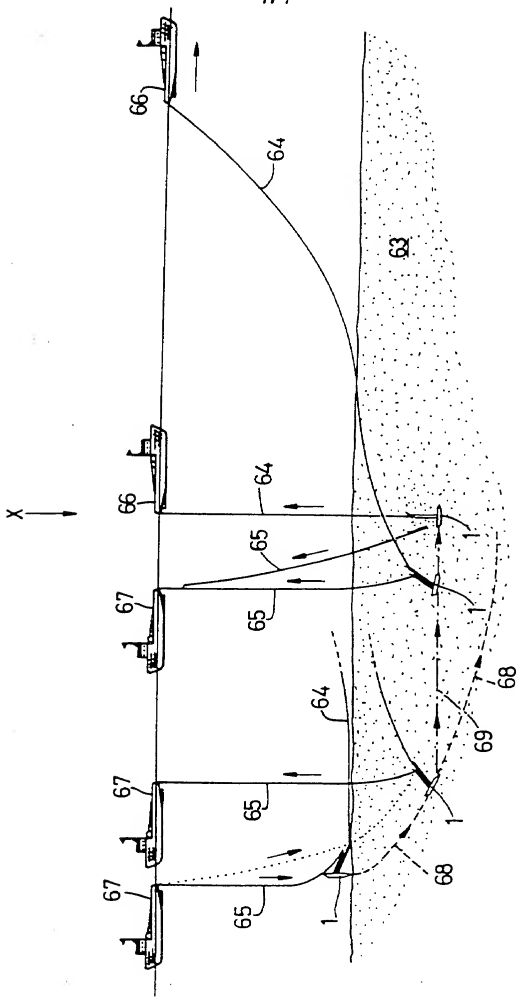

Fig.14

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 92/02210

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B63B21/26; B63B21/22; B63B21/44

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B63B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X Y A	US,A,3 407 775 (LUNDE) 29 October 1968 see the whole document	1,2,20 3-5 6-9,21, 22,23,25
Y	DE,C,168 099 (THE LANGSTON MOORING COMPANY G.M.B.H.) 12 November 1903 see the whole document	3,4,5
A	US,A,4 369 727 (FASCO) 25 January 1983 see the whole document	3,4
A	US,A,3 685 479 (BRUCE) 22 August 1972 see column 7, line 49 - column 8, line 48; figures 1-9	1

-/--

° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
23 FEBRUARY 1993	05. 03. 93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	DE SENA A.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	MARINE ENGINEERING AND SHIPBUILDING ABSTRACTS vol. 2, no. 2, 1972, 'vibratory anchor' see the whole document -----	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9202210 SA 67094

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 23/02/93
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-3407775		None		
DE-C-168099		None		
US-A-4369727	25-01-83	US-E-	RE31654	28-08-84
US-A-3685479	22-08-72	FR-A,B	2027067	25-09-70
		NL-A-	6919447	26-06-70
		GB-A-	1299366	13-12-72

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82